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KEIJI TOKIEDA residing at 2-20-204, Kaitori 2-chome, Tama-shi,
Tokyo, Japan, declares:

- (1) that he knows well both the Japanese and English languages;
- (2) that he translated the Japanese Patent Application No. 205165/99 from Japanese to English.
- (3) that the attached English translation is a true and correct translation of the above-identified Japanese Patent Application to the best of his knowledge and belief; and
- (4) that all statements made of his own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001, and that such false statements may jeopardize the validity of the application or any patent issuing thereon.

Dated: January 18, 2005

A handwritten signature in black ink, appearing to read "Keiji Tokieda", written over a horizontal line.

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(Document Name) SPECIFICATION

(Title of the Invention) CURABLE COMPOSITION

(Scope of Claims)

(Claim 1) A curable composition comprising:

a polymerizable monomer which, when homopolymerized, exhibits the L-scale Rockwell hardness of not larger than 40;

a polyfunctional polymerizable monomer which, when homopolymerized, exhibits the L-scale Rockwell hardness of not smaller than 60; and

a photochromic compound.

(Claim 2) A curable composition according to claim 1, wherein the polymerizable monomer which, when homopolymerized, exhibits an L-scale Rockwell hardness of not larger than 40, is one or more kinds of a polymerizable monomer selected from the group consisting of:

- (I) an ethylenic monofunctional unsaturated monomer;
- (II) a polyalkylene glycol polymerizable monomer of which one of a hydroxyl group at the terminal is terminated by methacryloyl group or acryloyl group, and of which the other group is terminated by methacryloyl group, acryloyl group, alkyl group, alkyl group, aryl group, epoxy group, haloalkyl group or oleyl group;
- (III) long-chain alkyl(meth)acrylate;
- (IV) an epoxy compound; and

(V) a thioepoxy compound;

and the polyfunctional polymerizable monomer which, when homopolymerized, exhibits the L-scale Rockwell hardness of not smaller than 60 is:

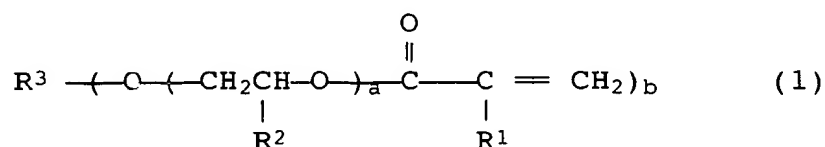
(VI) a polyfunctional polymerizable monomer containing at least three polymerizable groups in the molecule; and

(VII) a bifunctional polymerizable monomer containing two polymerizable groups in the molecule.

(Claim 3) A curable composition according to claim 2, wherein the polyalkylene glycol polymerizable monomer (II) is a polyalkylene glycol polymerizable monomer having a number-average molecular weight of from 200 to 1000;

the long-chain alkyl(meth)acrylate (III) is alkyl(meth)acrylate having an alkyl group containing 8 to 25 carbon atoms;

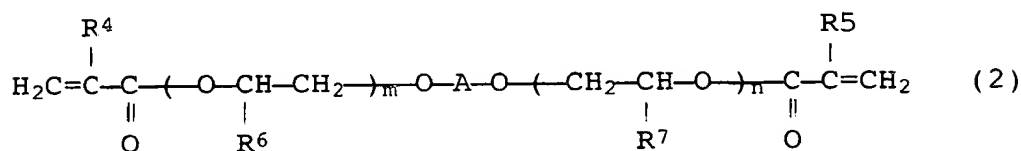
the polyfunctional polymerizable monomer (VI) is polyfunctional polymerizable monomer represented by the following general formula (1),



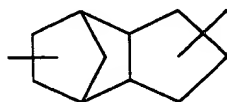
wherein R¹ and R² are, independently from each other, hydrogen atoms or alkyl groups having 1 to 2

carbon atoms, R^3 is a trivalent to hexavalent organic residue, a is an integer of 0 to 20, and b is an integer of 3 to 6,

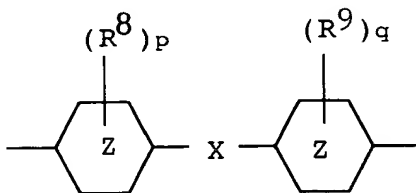
the bifunctional polymerizable monomer (VII) is a bifunctional polymerizable monomer represented by the following general formula (2),



wherein R^4 and R^5 are, independently from each other, hydrogen atoms or methyl groups, R^6 and R^7 are, independently from each other, hydrogen atoms or alkyl groups having 1 to 2 carbon atoms, A is a straight-chain or branched-chain alkylene group, a substituted or unsubstituted phenylene group, a group represented by the following formula,



or a group represented by the following formula,



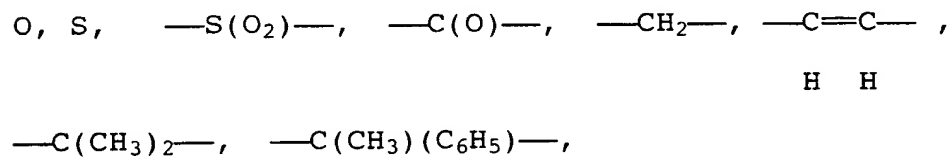
wherein R⁸ and R⁹ are, independently from each other, alkyl groups having 1 to 4 carbon atoms, chlorine atoms or bromine atoms, p and q are, independently from each other, integers of 0 to 4, a ring represented by the following formula



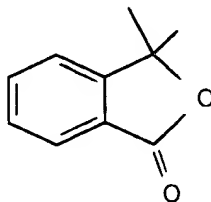
is a benzene ring or a cyclohexane ring, and when the ring represented by the following formula



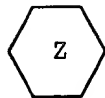
is a benzene ring, X is any one of the groups represented by the following formulas



or a group represented by the following formula



and when the ring represented by the following formula

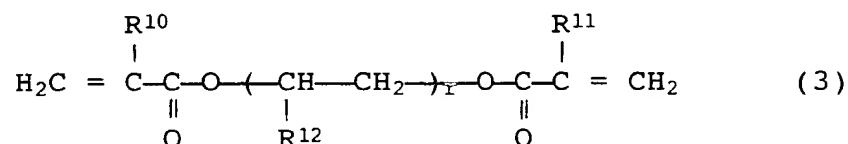


is a cyclohexane ring, X is any one of the groups represented by the following formulas



and m and n are an integer, respectively, and m + n is 1 to 10 in average,

or a bifunctional polymerizable monomer represented by the following general formula (3),



wherein R¹⁰ and R¹¹ are, independently from each other, hydrogen atoms or methyl groups, R¹² is a hydrogen atom or an alkyl group having 1 to 2 carbon atoms, and r is an integer of 1 to 10.

(Claim 4) A photochromic curable product obtained by curing the curable composition according to any one of claim 1 to claim 3.

(Detailed Description of the Invention)

(Industrial Field of Application)

The present invention relates to a novel photochromic cured product having excellent photochromic properties and matrix characteristics, and to a curable composition that yields the cured product.

(Prior Art)

Photochromism is a phenomenon that is drawing attention in these several years, and is a reversible action of a compound which quickly changes its color when it is irradiated with light containing ultraviolet rays such as sunlight or light of a fluorescent lamp and resumes its initial color when it is no longer irradiated with light but is placed in a dark place. The compound having this property is called photochromic compound. Various compounds have so far been synthesized but no particular common nature is recognized in their structures.

The present inventors have forwarded the study concerning a series of photochromic compounds, have succeeded in synthesizing novel photochromic compounds such as fulgimide compounds, spirooxazine compounds and chromene compounds, have discovered that these compounds exhibit excellent photochromic properties, and have already proposed these compounds.

Through the study conducted by the present inventors

up to know, it has been learned that the photochromic properties such as color density and fading rate of the photochromic compound are exhibited considerably sluggishly in the polymer as compared in a solution. This phenomenon becomes conspicuous particularly in a compound having photochromic molecules of large sizes. The development of this phenomenon is attributed to that free space in which the photochromic compound molecules are allowed to freely move is very limited in a matrix of polymer compared to that of in a solution.

In order to solve the above-mentioned problem, it can be contrived to make the base member soft by lowering the glass transition temperature of polymer of the matrix or to broaden free space in the matrix.

However, when a matrix having a low glass transition temperature is simply used, hardness is lost bringing about a problem when the composition is used for the applications where a hardness is required, such as lenses. Further, when polymer having large free space is used as a matrix, the hardness of the polymer is usually much dependent upon the temperature. Even those that exhibit a relatively high hardness near room temperature show a rapidly dropped hardness at high temperatures (hereinafter also referred to as having a low heat resistance) and further show a decreased impact resistance.

U.S. Patent No. 5395566 teaches that the use of a polymerizable monomer having an epoxy group in combination with a photochromic compound, helps improve light resistance for the photochromic properties. With the combination of the radical polymerizable monomers in the example of this specification, however, the physical properties of the base material, such as hardness and impact resistance are excellent, but in the case where the molecular size of the photochromic molecule is large, there are problems in that color density and fading rate are deteriorated.

The specification of U.S. Patent No. 5739243 teaches a system of a combination of a particular long-chain alkylene glycol dimethacrylate and a polyfunctional methacrylate having three or more radically polymerizable groups. From this combination is obtained a cured product having improved color density and fading rate. However, this technology is for obtaining a matrix excellent in flexibility. With this combination as shown in working examples, the matrix has such problems as a decreased hardness, a decreased heat resistance and much optical distortion.

Further, the specification of U.S. Patent No. 5811503 discloses a system of a combination of a long-chain alkylene glycol dimethacrylate and a dimethacrylate.

Though improved color-developing rate and fading rate are exhibited, this combination, too, has such defects that the matrix exhibits a decreased hardness, a decreased heat resistance and much optical distortion.

The specification of PCT International Patent Application 97/03373 discloses a combination of a dimethacrylate containing bisphenol A, a monofunctional styrene and a long-chain alkyl monofunctional methacrylate. However, this combination, too, has such defects that the matrix exhibits decreased hardness, a decreased heat resistance and much optical distortion.

As described above, no compound is ever satisfying both photochromic properties and matrix properties.

(Problems that the Invention is to Solve)

It is therefore an object of the present invention to provide a photochromic cured product exhibiting excellent photochromic properties such as a high color density and a large fading rate, and exhibiting excellent matrix characteristics such as a high hardness and a high heat resistance.

(Means of Solving the Problems)

The present invention was proposed in order to achieve the above object and was completed based on a knowledge that a cured product obtained by curing a curable composition obtained by mixing a photochromic compound with

a combination of particular polymerizable monomers, exhibits excellent photochromic properties such as a high color density and a large fading rate, as well as excellent matrix properties in regard to hardness and heat resistance.

That is to say, the present invention is a curable composition characterized by comprising: a polymerizable monomer which, when homopolymerized, exhibits the L-scale Rockwell hardness of not larger than 40, a polyfunctional polymerizable monomer which, when homopolymerized, exhibits the L-scale Rockwell hardness of not smaller than 60; and a photochromic compound.

The invention is further concerned with a photochromic cured product obtained by curing the above curable composition.

(Working Examples)

A polymerizable monomer (hereinafter also simply referred to as "low-hardness monomer") which is used for the curable composition of the invention and which, when homopolymerized, exhibits an L-scale Rockwell hardness of not larger than 40, may be any known polymerizable monomer without any particular limitation provided a homopolymer obtained by the homopolymerization exhibits the L-scale Rockwell hardness of not larger than 40.

The L-scale Rockwell hardness stands for a hardness

measured in compliance with JIS-B7726. That is, the homopolymers of the monomers are measured to easily judge whether the above hardness condition is satisfied. Concretely speaking, as will be described in Examples appearing later, the monomer is polymerized to obtain a cured product having a thickness of 2 mm, which is, then, preserved in a room maintained at 25°C for one day and is, then, measured for its L-scale Rockwell hardness by using a Rockwell hardness meter.

As the monomers that can be favorably used as low-hardness monomers, there can be mentioned, for example, polymerizable monomers shown in the compounds (I) to (V) described below, and a mixture of two or more kinds of polymerizable monomers optionally selected from these polymerizable monomers:

(I) An ethylenic monofunctional unsaturated monomer (hereinafter also simply referred to as "low-hardness monomer 1").

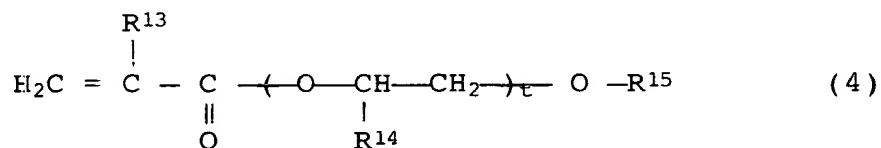
(II) A polyalkylene glycol polymerizable monomer (hereinafter also simply referred to as "low-hardness monomer 2") of which one of a hydroxyl group at the terminal is terminated by methacryloyl group or acryloyl group, and of which other group is terminated by methacryloyl group, acryloyl group, alkyl group, aryl group, epoxy group, haloalkyl group, or oleyl group;

- (III) Long-chain alkyl(meth)acrylate (hereinafter simply referred to as "low-hardness monomer 3");
- (IV) An epoxy compound (hereinafter simply referred to as "low-hardness monomer 4");
- (V) A thioepoxy compound (hereinafter simply referred to as "low-hardness monomer 5").

Examples that can be favorably used as the low-hardness monomer 1 include vinyl acetate, vinyl caproate, vinyl laurate, vinyl stearate and vinyl adipate.

The low-hardness monomer 2 is the one in which one of a hydroxyl group at a terminal of polyalkylene glycol is terminated by methacryloyl group, acryloyl group, (i.e., a structure terminated by the dehydration-condensation with methacrylic acid or acrylic acid), and the other group is terminated by methacryloyl group, acryloyl group, alkyl group, aryl group, epoxy group, haloalkyl group, or oleyl group.

Generally, there is exemplified a monomer having a structure represented by the following general formula (4),



wherein R¹³ and R¹⁴ are, independently from each

other, hydrogen atoms or alkyl groups having 1 to 2 carbon atoms, R^{15} is a hydrogen atom, an alkyl group having 1 to 25 carbon atoms, an aryl group, an alkyl group having an epoxy group at the terminal, a haloalkyl group, an oleyl group, a methacryloyl group, an acryloyl group, and t is an integer.

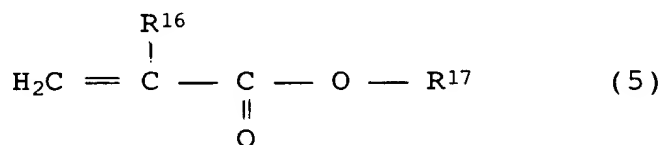
The monomer represented by the above general formula is usually obtained in the form of a mixture of molecules having different molecular weights. Therefore, t representing the numbers of the alkylene oxide units in the above formula (1), are expressed by average numbers of the units in the whole mixture. Here, t is generally from 4 to 70, in the case of being expressed in this manner.

As the low-hardness monomer 2, the one having a number-average molecular weight (hereinafter simply referred to as "average molecular weight") of from 200 to 2000 is preferably used. The average molecular weight can be determined by gel permeation chromatography (GPC) measurement.

Concrete examples of the low-hardness monomer 2 include a polyethylene glycol methacrylate having an average molecular weight of 526, a polyethylene glycol methacrylate having an average molecular weight of 360, a methyl ether polyethylene glycol methacrylate having an average molecular weight of 475, a methyl ether

polyethylene glycol methacrylate having an average molecular weight of 1000, a polypropylene glycol methacrylate having an average molecular weight of 375, a polypropylene glycol methacrylate having an average molecular weight of 430, a polypropylene glycol dimethacrylate having an average molecular weight of 875, and a polypropylene glycol methacrylate having an average molecular weight of 560.

The low-hardness monomer 3 is not particularly limited so long as it is (meth)acrylate having a long-chain alkyl group, and for example, there can be used a long-chain alkyl (meth)acrylate represented by the following general formula (5),



wherein R¹⁶ is a hydrogen atom or a methyl group, and

R¹⁷ is an alkyl group having 8 to 40 carbon atoms.

Among these long-chain alkyl (meth)acrylates, it is desired to use those in which R¹⁷ is an alkyl group having 8 to 25 carbon atoms, from the standpoint of easy availability of the starting material. Concrete examples of such a long-chain alkyl meth(acrylate) include stearyl methacrylate and lauryl methacrylate.

As the epoxy compound, which is the low-hardness

monomer 4, there can be exemplified (i) a reaction product of an alcoholic hydroxyl group-containing compound such as monohydric, dihydric or trihydric alcohol or a phenolic hydroxyl group-containing compound such as phenol or hydroquinone with epichlorohydrin, and (ii) a reaction product of a carboxylic acid such as benzoic acid or terephthalic acid with epichlorohydrin. Concrete examples of the above compound include ethylene glycol diglycidyl ether, propylene glycol diglycidyl ether, glycerol polyglycidyl ether, diglycerol polyglycidyl ether, sorbitol polyglycidyl ether, polyethylene glycol diglycidyl ether, polypropylene glycol diglycidylether, and bisphenol A or propylene oxide adduct of a hydrogenated bisphenol A.

As a thioepoxy compound, which is the low-hardness monomer 5, there can be mentioned (i) a reaction product of a thiolic hydroxyl group-containing compound such as a monohydric, dihydric or trihydric thiol or a thiophenolic hydroxyl group containing compound such as thiophenol or a thiohydroquinone with a thioepichlorohydrin, and (ii) or a reaction product of a thiocarboxylic acid such as thiobenzoic acid or thioterephthalic acid with a thioepichlorohydrin. Concrete examples of the above compound include ethylenethio glycol thioglycidyl ether, propylenethio glycol thioglycidyl ether, thioglycerol polythioglycidyl ether, thioglycerol polythioglycidyl

ether, thiosorbitol thioglycidyl ether, polyethylenethio glycol thioglycidyl ether, polypropylenethio glycol thioglycidyl ether, and thiopropylene oxide adduct of a thiobisphenol A or a hydrogenated thiobisphenol A.

As the polyfunctional polymerizable monomer used in the curable composition of the present invention which, when homopolymerized, exhibits an L-scale Rockwell hardness of not smaller than 60 (hereinafter, simply referred to as "high-hardness monomers"), it is not particularly limited, so long as it is a polyfunctional (that is, having at least two polymerizable groups in the molecule) polymerizable monomer in which the L-scale Rockwell hardness of a homopolymer obtained by homopolymerization is not smaller than 60, and known polymerizable monomers can be used without any limitation.

Any polymerizable group can be used without limitation provided it exhibits polymerizing property, and a group that exhibits radically polymerizable property is preferably used, such as methacryloyl group, acryloyl group, vinyl group and allyl group. Among them, methacryloyl group and acryloyl group are particularly preferred.

As the high-hardness monomers that can be favorably used, there can be mentioned polymerizable monomer, for example, shown in (VI) or (VII) described below, and a

mixture thereof. Confirmation of the L-scale Rockwell hardness is performed in the same manner as in the above-described low-hardness monomer:

(VI) a polyfunctional polymerizable monomer containing at least three polymerizable groups in the molecule (hereinafter, simply referred to as "high-hardness monomer 1");

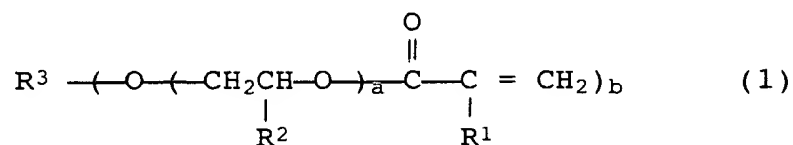
(VII) a bifunctional polymerizable monomer containing two polymerizable groups in the molecule (hereinafter, simply referred to as "high-hardness monomer 2").

As the polyfunctional polymerizable monomer of the high-hardness monomer 1, known polymerizable monomers can be used without any limitation, so long as it is a polymerizable monomer satisfying the hardness condition for the homopolymer, and having at least three polymerizable groups in the molecule. Desirably, there is used a polymerizable monomer having 3 to 6 polymerizable groups from the standpoint of easy availability on an industrial scale.

Preferred examples of the high-hardness monomer 1 include trimethacrylate derivative, triacrylate derivative, tetramethacrylate derivative, tetraacrylate derivative, triisocyanate derivative, tetraisocyanate derivative, triol derivative, trithiol derivative, tetrathiol derivative, triepoxy derivative, triurethane methacrylate derivative,

tetraurethane methacrylate derivative, hexaurethane methacrylate derivative, trivinyl derivative, tetravinyl derivative and triallyl derivative. Among them, there can be preferably used trimethacrylate derivative, triacrylate derivative, tetramethacrylate derivative, tetraacrylate derivative, triurethane methacrylate derivative, tetraurethane methacrylate derivative and hexaurethane methacrylate derivative having a methacryloyl group or an acryloyl group.

Among them, it is particularly desired to use a polyfunctional polymerizable monomer represented by the following general formula (1),



wherein R^1 and R^2 are, independently from each other, hydrogen atoms or alkyl groups (i.e., methyl groups or ethyl groups) having 1 to 2 carbon atoms, R^3 is a trivalent to hexavalent organic residue, a is an integer of 0 to 20, and b is an integer of 3 to 6,

from the standpoint of easy availability of the starting material and easiness for adjusting the hardness of the

cured product.

R^3 in the above general formula is not particularly limited, so long as it is a trivalent to hexavalent organic residue, and for example, there can be mentioned a trivalent to hexavalent organic residue derived from polyol, a trivalent to hexavalent hydrocarbon group, or a trivalent to hexavalent organic residue including an urethane bond.

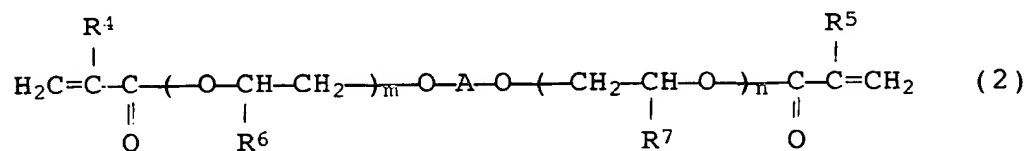
Concrete examples of the polyfunctional polymerizable monomer represented by the above general formula (1) that can be favorably used include a trimethylolpropane trimethacrylate, trimethylolpropane triacrylate, tetramethylolmethane trimethacrylate, tetramethylolmethane triacrylate, trimethylolpropane trimethacrylate, tetramethylolmethane tetramethacrylate, tetramethylolmethane tetraacrylate, trimethylolpropanetriethylene glycol trimethacrylate, trimethylolpropanetriethylene glycol triacrylate, ethoxylated pentaerythritol tetraacrylate, ethoxylated pentaerythritol tetramethacrylate, urethaneoligomer tetraacrylate and urethaneoligomer hexamethacrylate. These polyfunctional polymerizable monomers may be used being mixed together in two or more kinds.

As the bifunctional polymerizable monomer, being the above-described high-hardness monomer 2, known

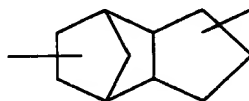
polymerizable monomers can be used without any limitation, so long as it is a polymerizable monomer satisfying the hardness condition for the homopolymer, and having two polymerizable groups in the molecule.

As the bifunctional polymerizable monomer that can be favorably used, there can be exemplified dimethacrylate derivative, diacrylate derivative, divinyl derivative, diallyl derivative, dicyano derivative, diol derivative, dithiol derivative, urethane dimethacrylate derivative, urethane diacrylate derivative, and diepoxy derivative. Among them, there can be exemplified dimethacrylate derivative, diacrylate derivative, urethane dimethacrylate derivative and urethane diacrylate derivative having a methacryloyl group or an acryloyl group.

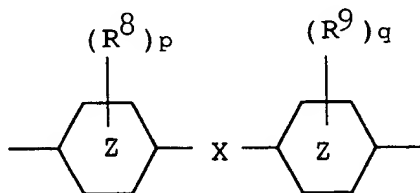
Among them, a bifunctional polymerizable monomer represented by the following general formula (2) or the following general formula (3) is particularly preferable, from the standpoint of easy availability of the starting materials and easily adjusting the hardness:
a bifunctional polymerizable monomer represented by:



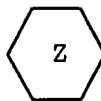
wherein R⁴ and R⁵ are, independently from each other, hydrogen atoms or methyl groups, R⁶ and R⁷ are, independently from each other, hydrogen atoms or alkyl groups having 1 to 2 carbon atoms, A is a straight-chain or branched-chain alkylene group, a substituted or unsubstituted phenylene group, a group represented by the following formula,



or a group represented by the following formula,



wherein R¹⁵ and R¹⁶ are, independently from each other, alkyl groups having 1 to 4 carbon atoms, chlorine atoms or bromine atoms, p and q are, independently from each other, integers of 0 to 4, a ring represented by the following formula

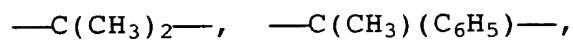
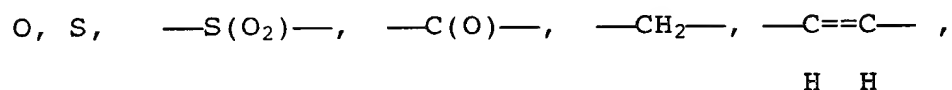


is a benzene ring or a cyclohexane ring, and when the

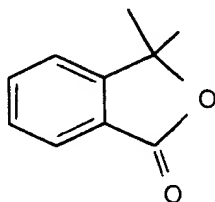
ring represented by the following formula



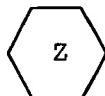
is a benzene ring, X is any one of the groups represented by the following formulas



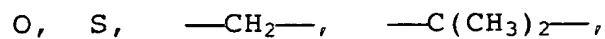
or a group represented by the formula



and when the ring represented by the following formula

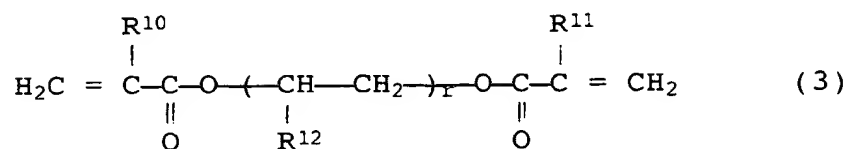


is a cyclohexane ring, X is any one of the groups represented by the following formulas



and m and n are an integer, respectively, and m + n is 2 to 6 in average.

or a bifunctional polymerizable monomer represented by:



wherein R¹⁰ and R¹¹ are, independently from each other, hydrogen atoms or methyl groups, R¹² is a hydrogen atom or an alkyl group having 1 to 2 carbon atoms, and r is an integer of 1 to 10.

The bifunctional polymerizable monomer represented by the above general formula (2) is usually obtained in the form of a mixture of molecules having different m and n. In the above formula, therefore, m and n represent values of m + n in average.

Concrete examples of the bifunctional polymerizable monomer include ethylene glycol diacrylate, diethylene glycol dimethacrylate, triethylene glycol dimethacrylate, tetraethylene glycol dimethacrylate, tripropylene glycol dimethacrylate, tetrapropylene glycol dimethacrylate, nonaethylene glycol dimethacrylate, nonapropylene glycol dimethacrylate, ethylene glycol bisglycidyl methacrylate, bisphenol A dimethacrylate, 2,2-bis(4-

methacryloyloxyethoxyphenyl)propane, 2,2-bis(3,5-dibromo-4-methacryloyloxyethoxyphenyl)propane, 1,4-butylene glycol ethylenedimethacrylate, 1,9-nonylene glycol dimethacrylate, neopentylene glycol dimethacrylate, and bis(2-methacryloyloxyethylthioethyl) sulfide. These bifunctional polymerizable monomers may be used in a mixture of two or more kinds.

The content of the low-hardness monomers and the high-hardness monomers in the curable composition of the present invention is not particularly limited. However, it is desired that the low-hardness monomers are used in amounts of from 1 to 50% by weight and, particularly, from 5 to 30% by weight, and the high-hardness monomers are used in amounts of from 50 to 99% by weight and, particularly, from 70 to 95% by weight based on the total weight of the monomers, from the standpoint of the effects of the present invention.

Moreover, from the standpoint of easy moldability of the cured product, with regard to the high-hardness monomer, it is desired to use the high-hardness monomer 1 and the high-hardness monomer 2, and the ratio thereof at that time is preferably such that the high-hardness monomer 1 is used in an amount of from 2 to 50% by weight and, particularly, from 5 to 40% by weight and the high-hardness monomer 2 is used in an amount of from 50 to 98% by weight

based on the weight of the whole high-hardness monomers.

Further, the curable composition of the present invention may be blended, as required, with other polymerizable monomers other than the low-hardness monomers and the high-hardness monomers within a range in which they will not impair the effect of the present invention.

Concrete examples of these polymerizable monomers (hereinafter also referred to as arbitrary monomers) include polymerizable monofunctional monomers, for example, polyallyl compounds such as diallyl phthalate, diallyl isophthalate, diallyl tartarate, epoxy dially succinate, diallyl fumarate, diallyl chlorendate, diallyl hexaphthalate, and allyl diglycol carbonate; polythioacrylic acid ester compounds and polythiomethacrylic acid ester compounds such as 1,2-bis(methacryloylthio)ethane, bis(2-acryloylthioethyl)ether, and 1,4-bis(methacryloylthiomethyl)benzene; unsaturated carboxylic acids such as acrylic acid ester compounds and methacrylic acid ester compounds such as glycidyl acrylate, glycidyl methacrylate, β -methylglycidyl methacrylate, bisphenol A-monoglycidyl ether-methacrylate, 4-glycidyloxy methacrylate, 3-(glycidyl-2-oxyethoxy)-2-hydroxypropyl methacrylate, 3-(glycidyloxy-1-isopropyloxy)-2-hydroxypropyl acrylate, 3-glycidyloxy-2-hydroxypropyloxy)-2-hydroxypropyl acrylate, acrylic acids, methacrylic acids

and maleic anhydride; acrylic acid ester compounds and methacrylic acid ester compounds such as methyl acrylate, methyl methacrylate, benzyl methacrylate, phenyl methacrylate and 2-hydroxyethyl methacrylate; fumaric acid ester compounds such as diethyl fumarate and diphenyl fumarate; thioacrylic acid and thiomethacrylic acid ester compounds, such as methyl thioacrylate, benzyl thioacrylate and benzyl thiomethacrylate; and vinyl compounds such as styrene, chlorostyrene, methylstyrene, vinyl naphthalene, α -methylstyrene dimer, bromostyrene, and divinyl benzene.

The above arbitrary monomers can be added in a single kind or being mixed in plural kinds together. The amount of addition is usually not larger than 40 parts by weight and, preferably, not larger than 30 parts by weight per a total amount of 100 parts by weight of the low-hardness monomers and the high-hardness monomers.

As the photochromic compound used in the curable composition of the present invention, any known photochromic compound can be used without limitation. Known examples of the photochromic compound are fulgimide compound, spirooxazine compound and chromene compound. In the present invention, it is allowed to use these photochromic compounds.

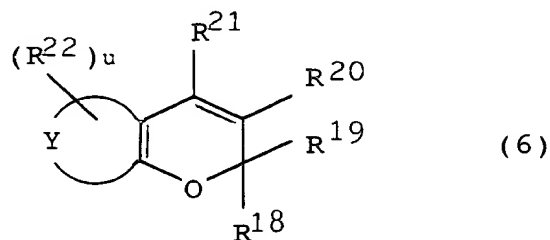
As the fulgimide compound, spirooxazine compound and chromene compound, there can be preferably used those

compounds that have been disclosed in, for example, Japanese Unexamined Patent Publication (Kokai) No. 28154/1990, Japanese unexamined Patent Publication (Kokai) No. 288830/1987, PCT International Patent Application No. 22850/1994, and PCI International Patent Application No. 14596/1996.

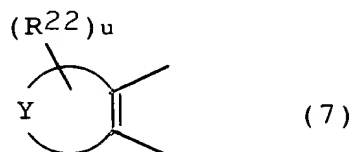
There can be further favorably used the compounds having excellent photochromic properties that newly discovered by the present inventions and are proposed in pending patent applications (Japanese Patent Applications Nos. 207871/1997, 23110/1999, 27959/1999, 27961/1999, 27960/1999, 140836/1999, 144072/1999, 150690/1999, 144074/1999, 156270/1999, 154272/1999, 188146/1999 and 188902/1999).

Among these photochromic compounds, a chromene compound exhibits photochromic properties maintaining light resistance larger than that of other photochromic compounds and, further, exhibits particularly greater color density and fading rate among other photochromic properties according to the present invention compared to those of other photochromic compounds, and can be favorably used.

As the chromene compound that can be favorably used in the present invention, there can be exemplified a compound represented by the following general formula (6),

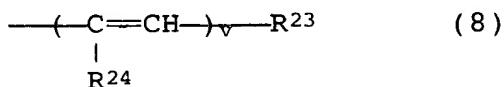


wherein a group represented by the following formula (7)



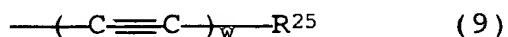
is a substituted or unsubstituted aromatic hydrocarbon group, or a substituted or unsubstituted unsaturated heterocyclic group, R^{20} , R^{21} and R^{22} are hydrogen atoms, alkyl groups, alkoxy groups, aralkoxy groups, amino groups, substituted amino groups, cyano groups, substituted or unsubstituted aryl groups, halogen atoms, aralkyl groups, hydroxy groups, substituted or unsubstituted alkynyl groups, substituted or unsubstituted heterocyclic groups containing a nitrogen atom as a hetero atom and in

which the nitrogen atom is bonded to a pyran ring or to a ring of the group represented by the above formula (7), or condensed heterocyclic groups in which the heterocyclic group is condensed with an aromatic hydrocarbon ring or an aromatic heterocyclic ring, u is an integer of 0 to 6, R¹⁸ and R¹⁹ are, independently from each other, groups represented by the following formula (8),



wherein R²³ is a substituted or unsubstituted aryl group, or substituted or unsubstituted heteroaryl group, R²⁴ is a hydrogen atom, an alkyl group or a halogen atom, and v is an integer of 1 to 3,

a group represented by the following formula (9),

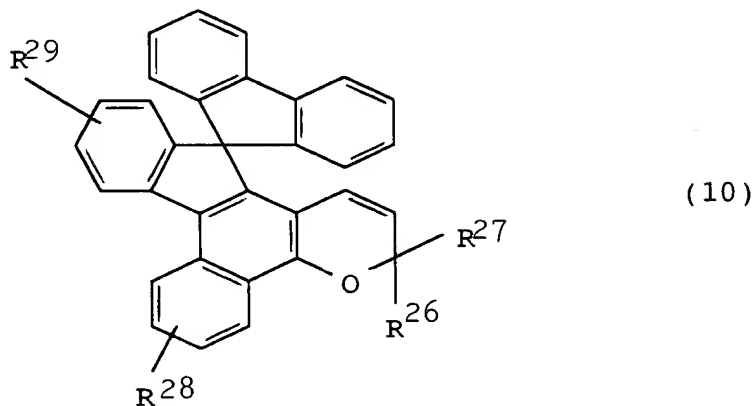


wherein R²⁵ is a substituted or unsubstituted aryl group, or a substituted or unsubstituted heteroaryl group, and w is an integer of 1 to 3, a substituted or unsubstituted aryl group, a

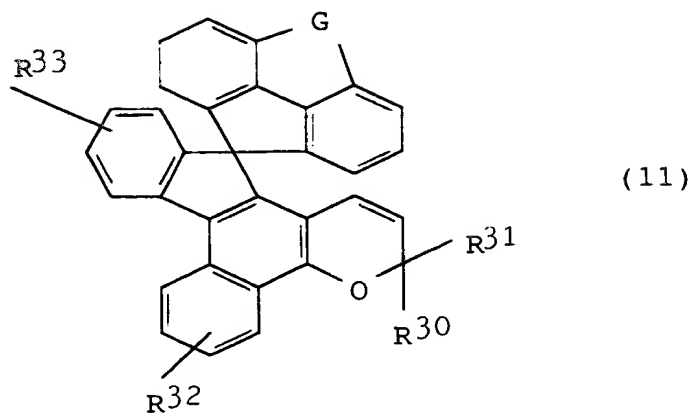
substituted or unsubstituted heteroaryl group, or an alkyl group, or R^{18} and R^{19} together may constitute an aliphatic hydrocarbon ring or an aromatic hydrocarbon ring.

Further, the substituents defined by R^{20} to R^{22} apply to the substituents in the substituted aryl group or in the substituted heteroaryl group described in the above formulas (8) and (9) and in connection with R^{18} and R^{19} .

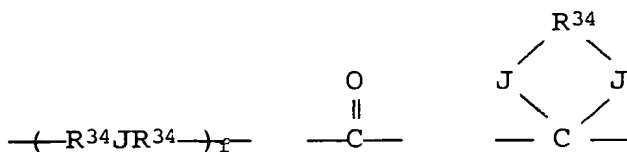
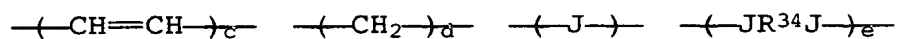
More preferred chromene compounds are those represented by the following general formulas (10) to (15),



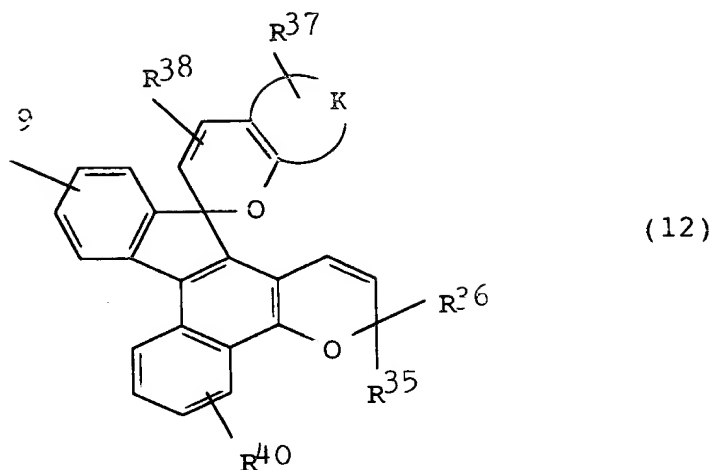
wherein R^{26} and R^{27} are as defined by R^{18} and R^{19} in the above formula (6), R^{28} and R^{29} are as defined by R^{20} , R^{21} and R^{22} in the above formula (6),



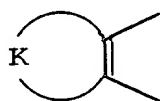
wherein R^{30} and R^{31} are as defined by R^{18} and R^{19} in the above formula (6), R^{32} and R^{33} are as defined by R^{20} , R^{21} and R^{22} in the above formula (6), and G is any one of the groups represented by the following formulas,



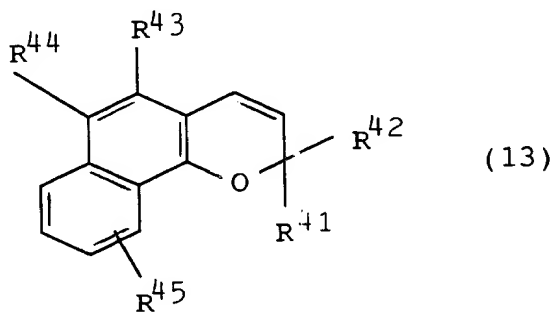
wherein J is an oxygen atom or a sulfur atom, R^{34} is an alkylene group having 1 to 6 carbon atoms, and c , d , e and f are integers of 1 to 4,



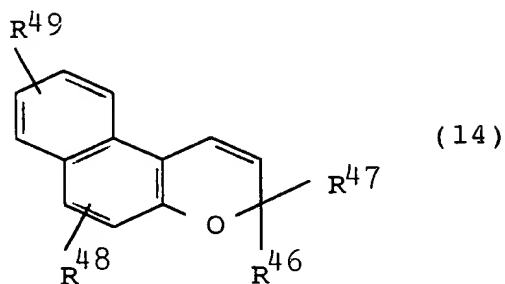
wherein R^{35} and R^{36} are as defined by R^{18} and R^{19} in the above formula (6), R^{37} , R^{38} , R^{39} and R^{40} are as defined by R^{20} , R^{21} and R^{22} in the above formula (6), and the following formula



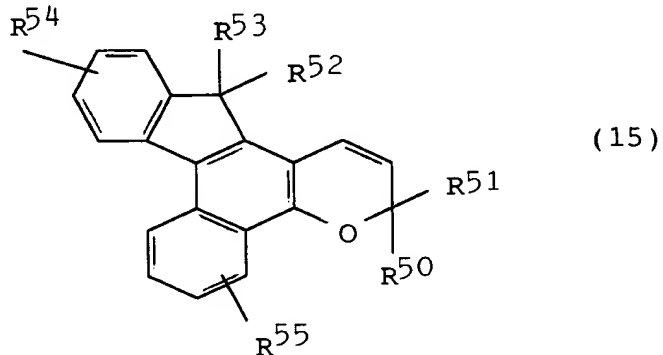
represents a substituted or unsubstituted aromatic hydrocarbon group, or a substituted or unsubstituted unsaturated heterocyclic group,



wherein R^{41} and R^{42} are as defined by R^{18} and R^{19} in the above formula (6), R^{43} , R^{44} and R^{45} are as defined by R^{20} , R^{21} and R^{22} in the above formula (6),



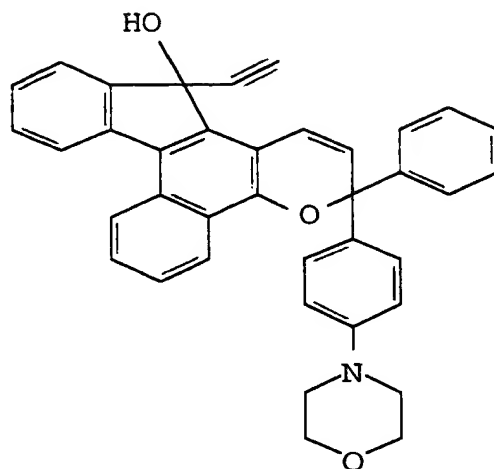
wherein R^{46} and R^{47} are as defined by R^{18} and R^{19} in the above formula (6), R^{48} , R^{49} and R^{50} are as defined by R^{20} , R^{21} and R^{22} in the above formula (6),



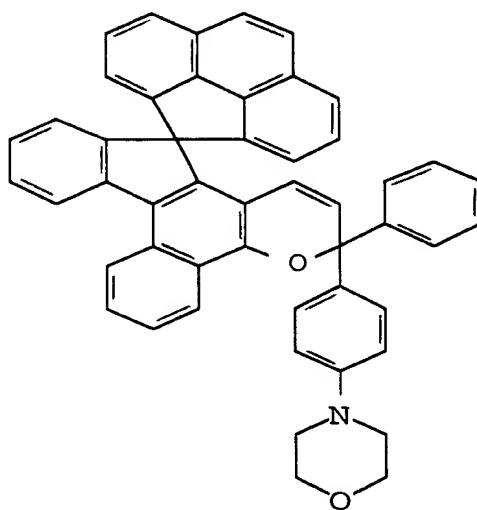
wherein R^{50} and R^{51} are as defined by R^{18} and R^{19} in the above formula (6), R^{52} , R^{53} , R^{54} and R^{55} are as defined by R^{20} to R^{22} in the above formula (6).
More preferred chromene compounds of the present

invention are those having structures as shown below.

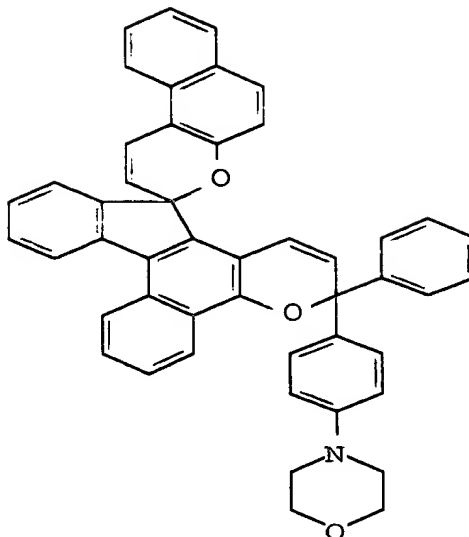
(Chemical F. 37)



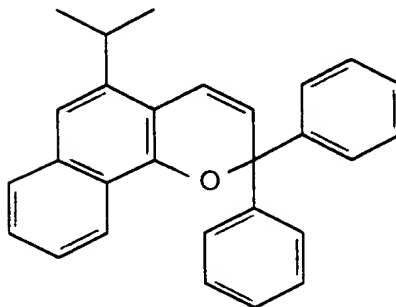
(Chemical F. 38)



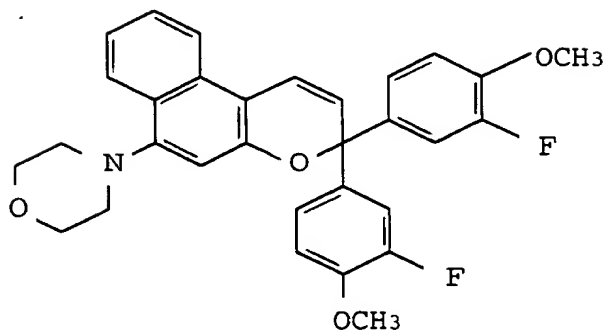
(Chemical F. 39)



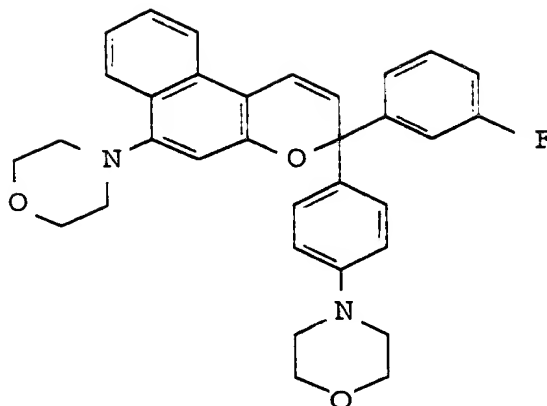
(Chemical F. 40)



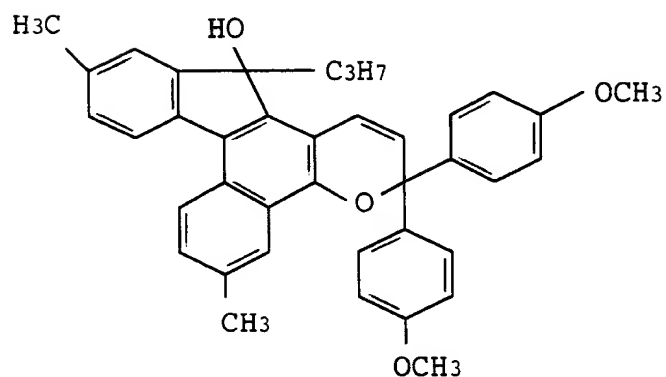
(Chemical F. 41)



(Chemical F. 42)



(Chemical F. 43)



In the curable composition of the present invention, there is no particular limitation on the amount of adding the photochromic compound. Generally, however, the amount of addition is from 0.001 to 5 parts by weight, preferably, from 0.005 to 1 part by weight and, more preferably, from 0.01 to 0.5 parts by weight per 100 parts by weight of all polymerizable monomers inclusive of arbitrary monomers.

When the amount of addition of the photochromic compound is smaller than 0.001 part by weight, the color density may decrease. When the amount of addition is greater than 5 parts by weight, the photochromic compound does not dissolve in the polymerizable monomers to a sufficient degree and becomes nonuniform, often giving rise to the occurrence of shading in the color density.

In order to improve light resistance, color-developing rate and color-fading rate of the photochromic compound, moldability, the curable composition of the present invention may be further blended with additives such as surfactant, antioxidant, radical-trapping agent, ultraviolet stabilizer, ultraviolet absorber, parting agent, coloring-preventing agent, antistatic agent, fluorescent dye, dye, pigment and perfume. Any known additives can be used without limitation.

As the surfactant, for example, there can be used any one of the nonionic type, anionic type or cationic type. From the standpoint of dissolution in the polymerizable monomer, however, it is desired to use a nonionic surfactant. Concrete examples of the nonionic surfactant that can be favorably used include sorbitan fatty acid ester, glycerin fatty acid ester, decaglycerin fatty acid ester, propylene glycol pentaerythritol fatty acid ester, polyoxyethylenesorbitan fatty acid ester,

polyoxyethylenesorbit fatty acid ester,
polyoxyethyleneglycerin fatty acid ester, polyethylene
glycol fatty acid ester, polyoxyethylenealkyl ether,
polyoxyethylenephytosterol phytostanol,
polyoxyethylenepolyoxypropylenealkyl ether,
polyoxyethylenealkylphenyl ether, polyoxyethylene castor
oil-cured castor oil, polyoxyethylenelanolin-lanolin
alcohol-bee wax derivative, polyoxyethylenealkylamine-fatty
acid amide, polyoxyethylenealkylphenylformaldehyde
condensation product, and single-chain polyoxyethylenealkyl
ether. The surfactants may be used being mixed in two or
more kinds. It is desired that the surfactants are added
in amounts of from 0.1 to 20 parts by weight per 100 parts
by weight of the total polymerizable monomers.

As the antioxidant, radical-trapping agent,
ultraviolet stabilizer and ultraviolet absorber, there can
be preferably used a hindered amine photostabilizer, a
hindered phenol antioxidant, a phenol-type radical-trapping
agent, sulfur-type antioxidant, benzotriazole compound and
benzophenone compound. The antioxidant, radical-trapping
agent, ultraviolet stabilizer and ultraviolet absorber may
be used being mixed in two or more kinds. In using these
nonpolymerizable compounds, there may be further used a
surfactant in combination with the antioxidant, radical-
trapping agent, ultraviolet stabilizer and ultraviolet

absorber. It is desired that the antioxidant, radical-trapping agent, ultraviolet stabilizer and ultraviolet absorber are added in amounts over a range of from 0.001 to 1 part by weight per 100 parts by weight of the whole polymerizable monomers.

There is no particular limitation on the method of preparing the curable composition of the present invention; i.e., the composition is prepared by weighing and mixing the components in predetermined amounts. There is no particular limitation on the order of adding the components. All components may be simultaneously added up. Or, the monomer components only may be mixed in advance and, then, for example, the photochromic compound and other additives may be added and mixed just prior to conducting the polymerization as will be described later. In conducting the polymerization as will be described later, a polymerization initiator may further be added as required.

There is no particular limitation on the method of obtaining a photochromic cured product by curing the curable composition of the present invention, and any known polymerization method can be employed depending upon the kinds of the monomers that are used. The polymerization can be initiated by using radical polymerization initiators such as various peroxides and azo compounds, or by being irradiated with ultraviolet rays, α -rays or γ -rays, or by

utilizing both of them.

Though there is no particular limitation on the polymerization method, it is desired to employ the cast polymerization from such a standpoint that the photochromic cured product may be used as a main body of the optical material such as of photochromic lenses. The representative cast polymerization will be described below in further detail.

In this method, the curable composition of the present invention to which a radical polymerization initiator is added, is poured into the mold that is held by an elastomer gasket or a spacer, and is heated in an air furnace so as to be polymerized and cured and is, then, taken out.

There is no particular limitation on the radical polymerization initiator, and any known compound can be used. Representative examples include diacyl peroxides such as benzoyl peroxide, p-chlorobenzoyl peroxide, decanoyl peroxide, lauroyl peroxide and acetyl peroxide; peroxy esters such as t-butylperoxy-2-ethyl hexanoate, t-butylperoxy dicarbonate, cumylperoxy neodecanate, and t-butylperoxy benzoate; percarbonates such as diisopropylperoxy dicarbonate, di-2-ethylhexylperoxy dicarbonate, and di-sec-butyloxy carbonate; and azo compounds such as 2,2'-azobisisobutyronitrile, 2,2'-azobis(4-dimethylvaleronitrile), 2,2'-azobis(2-

methylbutylonitrile), and 1,1'-azobis(cyclohexane-1-carbonitrile).

The amount of the radical polymerization initiator varies depending upon the polymerization conditions, kind of the initiator, kind and composition of the curable composition of the present invention, and cannot be exclusively specified. Generally, however, the radical polymerization initiator is used in an amount of from 0.01 to 10 parts by weight per 100 parts by weight of the whole polymerizable monomers.

Among the polymerization conditions, the temperature particularly affects the property of the obtained resin. The temperature varies depending upon the kind and amount of the initiator and the kind of the monomer, and cannot be exclusively specified. Generally, however, it is desired to conduct the so-called tapered two-stage polymerization in which the curing is effected by raising the temperature from a relatively low temperature, up to a high temperature, preferably, 70 to 120°C at the time when the polymerization is finished.

The polymerization time, too, varies depending upon various factors like the temperature, and it is desired to determine an optimum time in advance depending upon the conditions. Generally, it is desired to so select the conditions that the polymerization is completed in 2 to 40

hours.

The cast polymerization can be similarly conducted even by the known photo polymerization by using ultraviolet rays. As the photo polymerization initiator in this case, there can be used benzoin, benzoinmethyl ether, benzoinbutyl ether, benzophenol, acetophenone-4,4'-dichlorobenzophenone, diethoxyacetophenone, 2-hydroxy-2-methyl-1-phenylpropane-1-on, benzylmethylketal, 1-(4-isopropylphenyl)-2-hydroxy-2-methylpropane-1-on, 1-hydroxycyclohexylphenyl ketone, and 2-isopropylthioxanthone. In general, these photo polymerization initiators are used in an amount of from 0.001 to 5 parts by weight per 100 parts by weight of the whole monomers.

The cured product of the present invention obtained by the above-mentioned method can be processed in a manner as described below depending upon the applications. That is, the cured product is dyed by using a dye such as dispersion dye, is treated with a hard coating by using a silane coupling agent, a hard coating agent comprising chiefly a sol of an oxide of silicon, zirconium, antimony or aluminum, or a hard coating agent comprising chiefly an organic high molecules, is subjected to the anti-reflection treatment by being deposited with a thin film of a metal oxide such as SiO₂, TiO₂ or ZrO₂ or by being coated with a

thin film of organic high molecules, or is subjected to the antistatic treatment and a secondary treatment.

(Examples)

The present invention will be described in further detail to which only, however, the invention is in no way limited.

The compounds used in the following Examples are as described below.

(1) Low-hardness monomers.

The L-scale Rockwell hardnesses of the cured product obtained by homopolymerization may be hereinafter abbreviated simply as "homo-HL" (measuring method is described in ④ appearing later).

9PG: Nonapropylene glycol dimethacrylate (homo-HL < 20).

MAPEG (526): Polyethylene glycol methacrylate having an average molecular weight of 526.(homo-HL < 20).

DMAPEG (875): Polyethylene glycol dimethacrylate having an average molecular weight of 875.(homo-HL < 20).

MAPPG (430): Propylene glycol methacrylate having an average molecular weight of 430 (homo-HL < 20).

(2) High-hardness monomers.

TMPT: Trimethylolpropane trimethacrylate (homo-HL = 122).

ATM4E: Ethoxylated pentaerythritol tetraacrylate (homo-HL = 100).

U4HA: Urethane oligomer tetramethacrylate (homo-HL = 110).

High-hardness monomers 2:

4G: Tetraethylene glycol dimethacrylate (homo-HL = 90).

3G: Triethylene glycol dimethacrylate (homo-HL = 110).

BPE: 2,2-Bis(4-methacryloyloxyethoxyphenyl)propane (homo-HL = 110).

4PG: Tetrapropylene glycol dimethacrylate (homo-HL = 70).

(3) Arbitrary monomers.

GMA: Glycidyl methacrylate (homo-HL = 80).

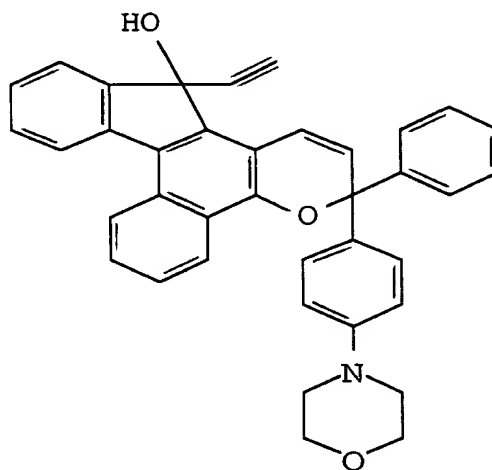
α MS: α -Methylstyrene (homo-HL < 40).

MSD: α -Methylstyrene (not homopolymerized).

(4) Photochromic compounds.

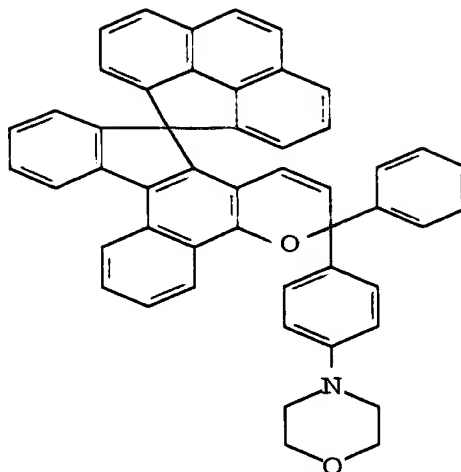
Chromene 1.

(Chemicals F. 44)



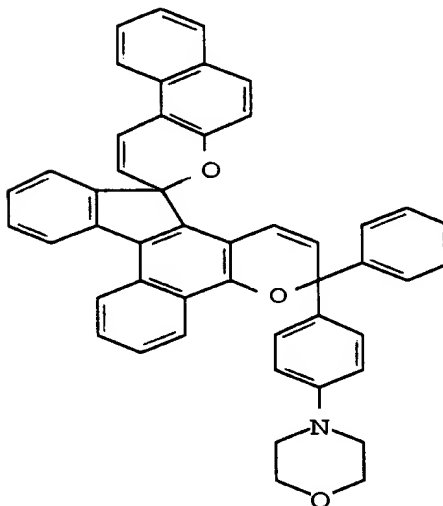
Chromene 2.

(Chemicals F. 45)



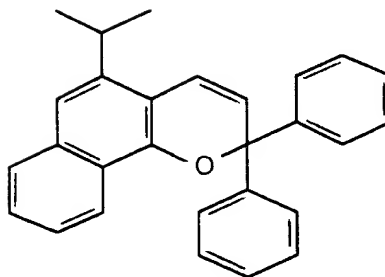
Chromene 3.

(Chemicals F. 46)



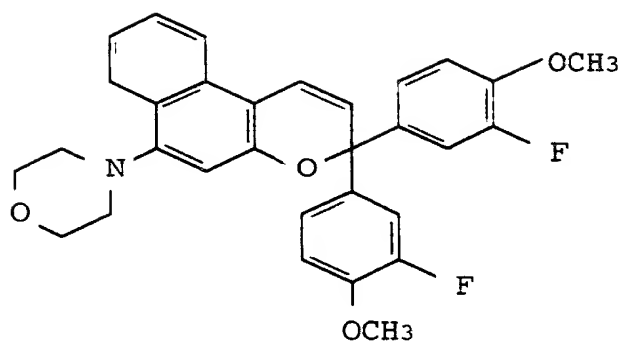
Chromene 4.

(Chemicals F. 47)



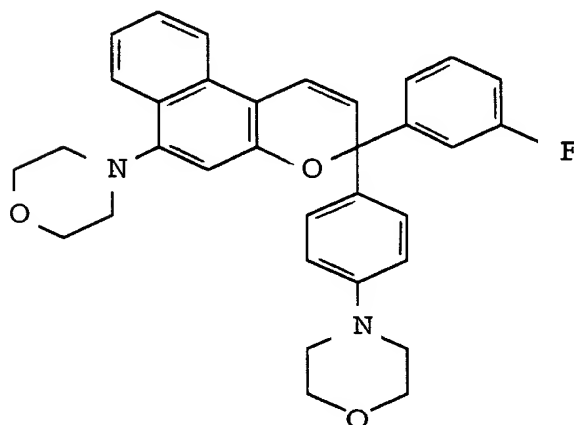
Chromene 5.

(Chemicals F. 48)



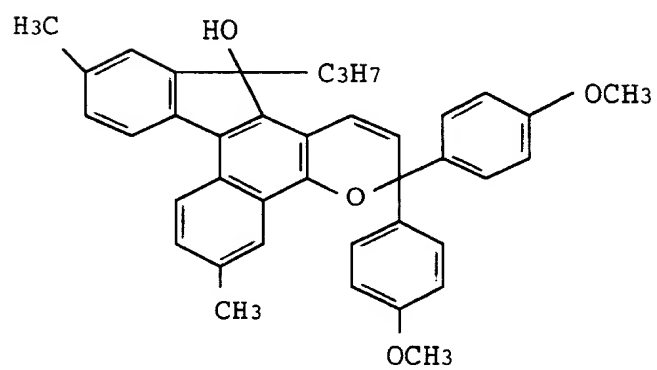
Chromene 6.

(Chemicals F. 49)



Chromene 7.

(Chemicals F. 50)



(5) Surfactant.

Tween 20: Polyoxyethylene (20) sorbitan monolaurate.

(6) Polymerization initiator.

Perbutyl ND: t-Butylperoxy neodecanate (trade name:

Perbutyl ND, produced by Nippon Yushi Co.).

(Example 1)

0.03 Parts by weight of the chromene 1 and 1 part by weight of the perbutyl ND as the polymerization initiator, were added to 100 parts by weight of polymerizable monomers comprising 20 parts by weight of TMPT, 55 parts by weight of tetraethylene glycol dimethacrylate, 7 parts by weight of glycidyl methacrylate, 5 parts by weight of α MS, 1 part by weight of MSD and 12 parts by weight of MAPEG 526, and were mixed to a sufficient degree. This mixture solution was poured into a mold constituted by a glass plate and a gasket of an ethylene/vinyl acetate copolymer, and was polymerized by cast polymerization. The polymerization was conducted by using an air furnace while gradually raising the temperature from 30°C to 90°C over a period of 18 hours and maintaining the temperature at 90°C for 2 hours. After the polymerization has been finished, the polymer was removed from the glass mold.

The thus obtained polymer sample (2 mm thick) was irradiated with light by using a xenon lamp L-2480 (300W) SHL-100 manufactured by Hamamatsu Photonics Co. through an

aeromass filter (manufactured by Coning Co.) at $20^{\circ}\text{C} \pm 1^{\circ}\text{C}$ at beam intensities on the polymer surface of $365\text{ nm} = 2.4\text{ mW/cm}^2$ and $245\text{ nm} = 24\text{ }\mu\text{W/cm}^2$ for 120 seconds to develop color and to measure the photochromic properties. The photochromic properties were evaluated by the following items;

- ① Maximum absorption wavelength (λ_{max}): A maximum absorption wavelength after the development of color as found by using a spectrophotometer (instantaneous multi-channel photodetector MCPD 1000) manufactured by Otsuka Denshi Co. The maximum absorption wavelength is related to the color tone at the time when the color is developed.
- ② Color density $\{\epsilon(120) - \epsilon(0)\}$: A difference between an absorbancy $\{\epsilon(120)\}$ after irradiated with light for 120 seconds at the maximum absorption wavelength and $\epsilon(0)$. It can be said that the higher this value, the more excellent the photochromic properties are.
- ③ Fading rate $[t_{1/2}(\text{min})]$: The time until the absorbancy of a sample at the maximum wavelength drops down to one-half the $\{\epsilon(120) - \epsilon(0)\}$ from when the sample is no longer irradiated with light after it was irradiated with light for 120 seconds. It can be said that the shorter the time, the more excellent the photochromic properties are.

Moreover, the properties of the base member were evaluated by the following items:

④ L-scale Rockwell hardness (HL): After left to stand in a room maintained at 25°C for one day, the cured product was measured for its L-scale Rockwell hardness by using the Akashi Rockwell hardness meter (model, AR-10).

⑤ Impact resistance: A steel ball was permitted to naturally fall on a test plate having a thickness of 2 mm and a diameter of 65 mm from a height of 127 cm, and the impact resistance was evaluated in terms of the weight of the steel ball by which the test plate was broken. The basis of evaluation was such that "1" was when the weight of the steel ball at this moment was smaller than 20 g, "2" was when the weight was 20 to 40 g, "3" was when the weight was 40 to 60 g, "4" was when the weight was 60 to 80 g, and "5" was when the weight was not smaller than 80 g.

⑥ Heat resistance: The molded and cured product was fitted to the frame and was heated at 120°C. ○ represents the case when the frame was not deviated, and × represents the case when the frame was deviated.

The results are shown in Table 1.

Table 1

Ex. No.	Low-hardness monomer (parts by wt)	High-hardness monomer (parts by wt)	Arbitrary monomer (parts by wt)	Other additives (parts)	Chromene compound (parts)
1	MAPEG(526) 5	TMPT/4G 5/77	GMA/ α MS/MSD 7/5/1	—	chromene 1 0.03
2	MAPEG(526) 10	TMPT/4G 20/57	GMA/ α MS/MSD 7/5/1	—	chromene 1 0.03
3	MAPEG(526) 20	TMPT/4G 40/27	GMA/ α MS/MSD 7/5/1	—	chromene 1 0.03
4	MAPEG(526) 10	TMPT/U4HA/4G 20/10/47	GMA/ α MS/MSD 7/5/1	—	chromene 1 0.03
5	MAPPG(430) 5	TMPT/4PG 10/85	—	—	chromene 1 0.03
6	MAPPG(430) 10	TMPT/4PG 25/65	—	—	chromene 1 0.03
7	MAPPG(430) 20	TMPT/4PG 40/40	—	—	chromene 1 0.03
8	MAPPG(430) 10	TMPT/U4HA/4PG 20/13/57	—	—	chromene 1 0.03
9	C18MA 10	TMPT/BPE/3G 20/35/20	GMA/ α MS/MSD 9/5/1	—	chromene 2 0.03
10	MAPPG(430) 15	TMPT/BPE/4PG 20/20/30	GMA 15	—	chromene 2 0.03
11	MAPEG(526)/ MAPPG(430) 5/5	TMPT/U4HA/BPE/4PG 20/10/45	GMA/MSD 14/1	—	chromene 2 0.03
12	DMPEG(875) 20	TMPT/4G/3G 20/45/12	GMA 15	—	chromene 2 0.03
13	MAPEG(526) 12	ATM4E/4G 48/40	—	—	chromene 3 0.03
14	MAPPG(430) 10	TMPT/4PG 20/55	α MS 15	—	chromene 3 0.05
15	MAPPG(430) 15	TMPT/BPE/4PG 20/35/28	MSD 2	—	chromene 4 0.05
16	MAPEG(526) 10	TMPT/4G 20/57	GMA 15	—	chromene 5 0.05
17	9PG 30	TMPT/4G/3G 30/20/5	GMA 15	—	chromene 5 0.05
18	MAPEG(526) 15	TMPT/ATM4E/4PG 20/35/30	—	—	chromene 6 0.03
19	DMPEG(875) 20	TMPT/4G/3G 20/45/12	GMA 13	—	chromene 7 0.03
20	DMPEG(875) 20	TMPT/4G/3G 20/45/12	GMA 13	Tween20 0.5	chromene 7 0.03

Table 1(continued)

<u>Ex. No.</u>	<u>λ Max (nm)</u>	<u>Color density</u>	<u>Fading rate (min)</u>	<u>HL hardness</u>	<u>Heat resistance</u>	<u>Impact resistance</u>
1	586	0.8	2	88	○	4
2	586	1.1	1	96	○	4
3	586	1.3	0.6	100	○	3
4	586	0.9	1	94	○	5
5	584	0.9	1.5	86	○	3
6	584	1.2	0.8	93	○	3
7	584	1.4	0.5	100	○	3
8	584	1	0.9	95	○	4
9	580	0.72	0.6	94	○	4
10	580	0.8	0.5	96	○	4
11	580	0.82	0.5	95	○	5
12	580	0.9	1.1	95	○	4
13	580	1	1.5	90	○	3
14	580	1	1.8	93	○	4
15	478	1.5	2.5	96	○	4
16	442	1.2	1.1	96	○	3
17	442	1.1	1.3	100	○	3
18	478	1.2	1	88	○	3
19	576	0.8	2.5	92	○	3
20	576	0.9	2	91	○	3

(Examples 1 to 20)

Photochromic cured products were obtained in the same manner as in Example 1 but using polymerizable monomer composition , chromene compounds and other additives shown in Table 1, and were evaluated for their photochromic properties. The results are shown in Table 1 together.

(Comparative Examples 1 to 9)

Moreover, for comparison sake, photochromic cured products were obtained in the same manner as in Example 1, except that the polymerizable monomer compositions and chromene compounds as shown in Table 2 were used, and the photochromic properties were evaluated. The evaluation results are shown in Table 2.

Table 2

Comp. Ex. No.	Low-Hardness monomer (parts by wt.)	High-Hardness monomer (parts by wt.)	Arbitrary monomer (parts by wt.)	Other additives (parts)	Chromene compound	λ_{\max} (nm)	Color density	Fading rate (min)	HL hardness	Heat resistance	Impact resistance
1	—	4G 85	GMA/ α MS/MSD 9/5/1	—	chromene 1 0.03	584	0.5	4.6	95	O	5
2	—	TMPT 85	GMA/ α MS/MSD 9/5/1	—	chromene 1 0.03	582	0.9	1.5	120	X	1
3	MAPEG(526) 85	—	GMA 15	—	chromene 1 0.03	584	1.1	1	<10	X	5
4	—	4G 85	GMA/ α MS/MSD 9/5/1	—	chromene 2 0.05	584	0.3	2	95	O	5
5	—	4G 85	GMA 15	—	chromene 3 0.05	584	0.4	4	95	O	5
6	—	4G 85	GMA 15	—	chromene 4 0.05	478	1	6	95	O	5
7	—	4G 85	GMA 15	—	chromene 5 0.03	442	1	3	95	O	5
8	—	4G 85	GMA 15	—	chromene 6 0.03	478	1	3	95	O	5
9	—	4G 85	GMA 15	—	chromene 7 0.03	574	0.3	5.5	95	O	5

(Document Name) ABSTRACT

(Summary)

(Purpose) To provide a photochromic cured product having high color density, large fading rate and exhibiting excellent photochromic properties, and further exhibiting excellent properties of the base member, such as hardness, heat resistance and impact resistance of the cured product.

(Composition) A curable composition contains a polymerizable monomer having the L-scale Rockwell hardness of not larger than 40 such as nonapropylene glycol dimethacrylate, a polyfunctional polymerizable monomer having the L-scale Rockwell hardness of not smaller than 60 such as trimethylolpropane methacrylate, and a photochromic compound is polymerized and cured.

(Selected Drawing) None